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Archival Automatic Identification System (AIS) Data for Navigation Project Performance Evaluation

by Brandan Scully and Kenneth Ned Mitchell

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) describes Automatic Identification System (AIS) technology in general and highlights the growing availability of and potential applications of AIS data for performance evaluation of navigation projects. In particular, archived AIS data may be used in a variety of investigations and designs as the U.S. Army Corps of Engineers (USACE) executes its civil works mission. Uses range in complexity from simple reconnaissance and visualization of parameter-based queries to complex analysis of vessel behavior coupled with environmental input such as tidal elevations and wave conditions. Additional uses for modeling and engineering design are currently being investigated through the Navigation Systems (NavSys) research and development program as well as the Coastal Inlets Research Program (CIRP). An AIS data analysis package being developed jointly by these two programs is also described.

BACKGROUND: Automatic Identification System technology was primarily developed to aid in the improvement of marine safety and maritime domain awareness. Commercial off-the-shelf AIS transponders foster increased communication and awareness by providing a real-time graphical interface that displays the location, heading, course, and speed of properly equipped broadcasting vessels or stations. The AIS data standard is published by the International Telecommunication Union (ITU). As of this writing, AIS supports 27 message types as described by that body's latest recommendation document ITU-R M.1371-4 (ITU 2010).

In the US, 33 CFR § 164 mandates carriage requirements for certain commercial vessels and designates responsibility for enforcement of equipment carriage, message formatting, and data archiving with the U.S. Coast Guard (USCG 2013). The USCG and USACE currently have a memorandum of understanding (MOU) for partnering to collect and share AIS data more readily. The types of data-sharing categories and requirements may be viewed through the Coast Guard's Navigation Center website: *http://www.navcen.uscg.gov/*. Access to the AIS archival data is presently provided through the USCG online request form, also via the Navigation Center website. As these requests are processed manually by USCG personnel, this process typically takes anywhere from several days to weeks depending on the number of pending requests, and care should be taken to ensure that all required data fields are included in the original request. An alternative access point for USACE practitioners is provided through a series of web services provided by the USCG to obtain AIS data directly.

OVERVIEW: The need to collect-vessel related information for waterway-related investigations and designs for USACE civil works projects is well documented. Frequently, vessel speed is required as an input to wake and erosion analysis in the nearshore environment and to determine transit times through a waterway. Vessel position has been recorded using deployed GPS receivers to realign navigation channels when existing designs experienced adverse conditions.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
AUG 2015		**00-00-2015 to 00-00-2015**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Archival Automatic Identification System (AIS) Data for Navigation Project Performance Evaluation	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Engineer Research and Development Center,,Vicksburg,,MS**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This Coastal and Hydraulics Engineering Technical Note (CHETN) describes Automatic Identification System (AIS) technology in general and highlights the growing availability of and potential applications of AIS data for performance evaluation of navigation projects. In particular, archived AIS data may be used in a variety of investigations and designs as the U.S. Army Corps of Engineers (USACE) executes its civil works mission. Uses range in complexity from simple reconnaissance and visualization of parameter-based queries to complex analysis of vessel behavior coupled with environmental input such as tidal elevations and wave conditions. Additional uses for modeling and engineering design are currently being investigated through the Navigation Systems (NavSys) research and development program as well as the Coastal Inlets Research Program (CIRP). An AIS data analysis package being developed jointly by these two programs is also described.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a REPORT	b ABSTRACT	c THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**11**	

Information about the number and types of ships transiting a waterway are required for economic analysis performed to support feasibility studies. These and a variety of frequently required parameters are listed in the Coastal Engineering Manual 1110-2-1100 (USACE 2002), Hydraulic Design of Deep Draft Navigation Projects, EM-1110-2-1613 (HQUSACE 2006), and elsewhere. The data contained in archived AIS signals and available to USACE practitioners via the MOU mentioned above provides several of these parameters at a cost that is significantly lower than traditional practices (e.g., onboard GPS units, shore-based filming, etc.).

AIS data were broadcast and recorded according to the ITU standard previously mentioned. Of 27 unique message types, those of interest to this study can be broadly classified as position (ID 1, 2, 3, 18, 19, 21 & 27) or static reports (ID 5) and will be most useful for evaluation of navigation project performance. Position reports are of particular interest because they identify the time-stamped latitude and longitude, heading, course over ground, speed over ground, and rate of turn of the vessels broadcasting the signal. Static data reports provide information including vessel identifying information, dimensions, ship and cargo type, and origin and destination. Table 1 lists the typical information available in position and static reports.

Table 1 – Static and position report contents available from AIS Records, via USCG historic data request (ITU 2010).

Attribute Heading	Data Type	Message Type	Attribute Description
MMSI	Integer	Dynamic	Vessel unique ID; crosswalk to static data
TX_DTTM	Date	Dynamic	Date-time stamp
LAT	Float	Dynamic	Latitude coordinate in decimal degrees
LON	Float	Dynamic	Longitude coordinate in decimal degrees
COURSE_OVER_GROUND	Integer	Dynamic	0 to 3600; based on actual track, no heading
NAV_STATUS	Integer	Dynamic	i.e., Underway, at anchor, stopped, etc.
POS_ACCURACY	Binary	Dynamic	Indication of position accuracy
RATE_OF_TURN	Integer	Dynamic	Positive values for right turns, negative for left
SPEED_OVER_GROUND	Integer	Dynamic	Vessel speed in knots
HEADING	Integer	Dynamic	0 to 3600; based on vessel heading, not track
MMSI	Integer	Static	Vessel unique ID; crosswalk to dynamic data
IMO_NUMBER	Integer	Static	International Maritime Organization unique ID
CALL_SIGN	Text	Static	Vessel call sign, alternate unique ID
NAME	Text	Static	Vessel Name
SHIP_AND_CARGO_TYPE	Integer	Static	Indicates type of vessel and cargo type
DIM_BOW	Integer	Static	Distance from AIS unit to ship bow
DIM_STERN	Iteger	Static	Distance from AIS unit to ship stern
DIM_PORT	Integer	Static	Distance from AIS unit to ship port side
DIM_STARBOARD	Integer	Static	Distance from AIS unit to ship starboard side
DRAUGHT	Integer	Static	Vessel draft
NAV-SENSOR	Integer	Static	Source of vessel position data (e.g. GPS)
ETA	Date	Static	operator input, estimated arrival time
DESTINATION	Text	Static	Vessel operator input, voyage destination

Individual reports as recorded by the US Coast Guard are stored as database records in National Marine Electronics Association (NMEA) format. Archival data requested from the USCG can be received in a variety of formats, including readable *.CSV files, *.XML format, and *.KML for viewing in Google Earth. A unique vessel identifier is provided in position and static reports, enabling table relationships and processing with common database techniques. This allows for spatio-temporal analysis of highly detailed data packages representing vessels operating in the waterway. This also allows for verification of reported vessel information with authoritative data such as the U.S. Coast Guard Port State Information eXchange (available at *http://cgmix.uscg.mil/psix/*) or through proprietary or owner means. Verification by the Authoritative Vessel Information Service (AVIS) is performed by request through the USCG data request portal mentioned previously. Similar verification is required for validation of vessel characteristics if the AIS data were independently collected and not processed by the USCG. Data checked against an authoritative database, such as AVIS data received through the USCG historical data request portal, were strongly recommended and most suitable for USACE studies.

VESSEL SPECIFIC INFORMATION: Information contained in AIS records ranges in complexity. Identifying information, including vessel name, maritime mobility service identifier (MMSI), call sign, international maritime organization (IMO) number, etc., is self explanatory; however in some instances it is necessary to verify this information. Since several of the AIS fields are input manually, misspellings and number transpositions are common. Also, default settings and other common false entries, such as "123456789" for MMSI, may make determining the accuracy of this data difficult.

AIS data incorporate a ship and cargo type identifier, as shown in Table 1. This is a broad classification as described in the ITU standard. It is useful for determining the makeup of vessel populations on a particular waterway and can be used as an input to economic and engineering analyses. For example, vessels coded 50 are pilot vessels, 52 are tugs, and 60-coded vessels are passenger vessels. Some vessels have entire series, such as cargo vessels (7X), where X is a descriptive variable from TABLE 50 of ITU (2010), tank vessels (8X), and special operations vessels such as dredges (3X).

Vessel-specific information is useful for developing an understanding of vessels using a particular waterway. Current practice for determining vessel population composition and navigation feature use relies on dock-level information provided by waterfront entities to the USACE Master Docks program (*http://www.navigationdatacenter.us/ports/ports.asp*) at the Navigation and Civil Works Decision Support Center. This information is distilled into commodity information, and interpretations of vessel origin and destination records are made to determine navigation channels transited. This is a lengthy process, often taking a year or longer to generate useful data. In contrast, AIS position records with embedded ship and cargo type can be analyzed spatially to make direct observations of waterway users, in real time if desired.

Figure 1 provides an example of vessels observed (i.e., broadcasting AIS signals) to be operating in Charleston Harbor's Bennis Reach channel during January, 2011. Note that in addition to population histograms, summary statistics, speed and vessel characteristic (length, width, draft) histograms, and a directionality plot are also derived. An AIS data handling and analysis application being developed jointly within the CIRP and NavSys research programs is used to generate the summary statistics and charts shown in Figure 1.

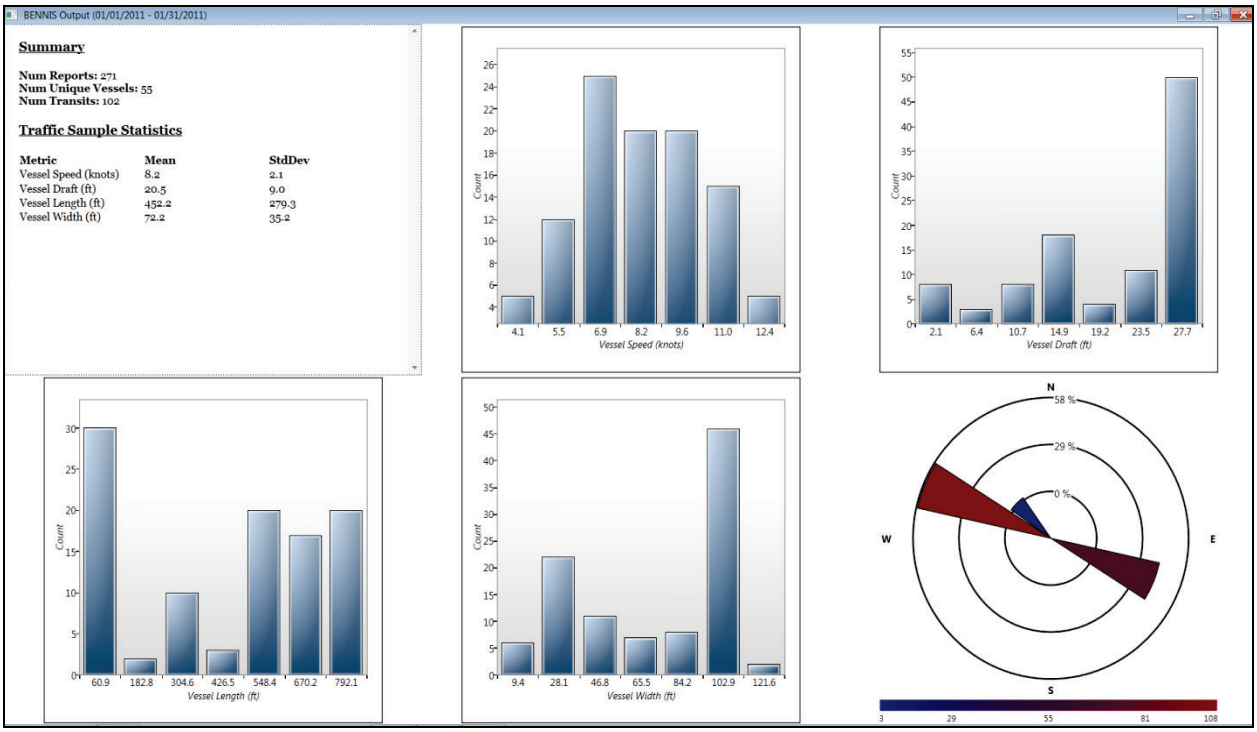

Figure 1. Composition of vessels transiting Charleston Harbor's Bennis Reach automatically derived from AIS records for January, 2011.

AIS position reports use the WGS 1984 datum in geographic coordinates. This position is derived from the ship's onboard GPS navigation system. Vertical position is not available from the AIS signal record. The reporting interval is based on vessel speed according to the ITU (2010) standard, with higher speeds reporting more frequently. Vessels may also decrease reporting period during turns. Table 2 lists the reporting interval specifications.

Table 2 – Nominal vessel reporting intervals and dynamic conditions. From Table 1 of ITU (2010).

Report Interval	Dynamic Condition
2 s	Ships 14 – 23 knots and changing course, or ships > 23 knots
3 1/3 s	Ship 0 – 14 knots and changing course
6 s	Ship 14 – 23 knots
10 s	Ship 0 – 14 knots, or ship at anchor/moored moving > 3 knots
3 m	Ship at anchor/moored and not moving faster than 3 knots.

The location of AIS broadcast antennae with respect to vessel bow, stern, port, and starboard sides is embedded in the static vessel data. From this information, it is possible to derive the length and beam of a broadcasting vessel. Alternatively, the length can be derived or corroborated using authoritative sources that cross reference the MMSI number with various ship registries and databases. The maximum present draft is reported as "Draught" directly. The sailing draft may be reported, but more likely this parameter represents maximum or design draft. Field investigation or record review should be made if highly accurate draft data is required.

With all three vessel dimensions known, or at least assumed based on vessel class, ship parameters such as length, beam, draft, block coefficient (Maynord 2007), propeller coefficient (Hammack and Tate 2008), and others can be calculated, assumed, or otherwise derived. By incorporating the vessel dimensions with respect to the broadcast location, and vessel heading which is also available, AIS provides the ability to give a detailed understanding of vessel attitude during operation (similar analysis was performed by Webb (1998) using GPS-derived data). Vessel performance information can be screened for a variety of embedded factors in the context of navigation features, such as inbound or outbound vessels. Vessel behavior in meeting or overtaking maneuvers may be observed. In essence, compiled AIS records should be viewed as a remote sensing technology capable of supporting quantitative analysis of vessel performance and behavior within and near federal navigation projects.

POTENTIAL APPLICATIONS: A variety of applications for AIS data exist towards developing improved understandings of navigation project performance. One such application is the ability to correlate vessel characteristics to other phenomena, such as winds, waves, tide, adverse currents, and day/night condition. These applications require in-depth study and are not explored here. However, the following applications should provide the basis for further investigation of AIS data use.

Channel Alignment. It is frequently necessary to understand vessel tracks used in waterway transit and dock approaches. This is useful in the design stages for channel alignment and other navigation features. For example, a field data team was deployed to the underway *MV MOL ENDOWMENT* for the purpose of collecting track and image data to support vessel simulation as part of the ongoing Charleston Harbor Deepening Feasibility Study. The observation team used hand-held GPS receivers to plot the vessel's track from the port and starboard bridge wings. Following field data collection, AIS data for this transit were extracted from the historical aggregate record for comparison. Figure 2 shows an AIS data record compared to data obtained by traditional observation methods.

The red and green lines shown in Figure 2 were derived from the data points collected using typical GPS methods. The blue dots and black arrows are discrete AIS position reports provided by the USCG, with the black arrows representing vessel heading. The inset images highlight the points at which onboard field GPS observations were established and suspended. Position accuracy is similar to manual collection, yet AIS data provides triple the data volume for this single transit, with no explicit cost incurred. Each historical data request from the USCG will result in a similar volume of data for each transit (inbound and outbound) of all broadcasting ships (or fewer, as specified) in US waters with AIS coverage, for a period of up to 3 years (the statutory data-retention period). The fact that AIS cannot be used to collect other field data, such as harbor images, must be weighed against the fact that many more vessel position reports are available through archival AIS records than can be economically collected using field observation.

Vessel Performance. Vessel position reports may be analyzed for a variety of metrics pertaining to vessel performance within a waterway. For instance, the duration of similar transits (i.e., inbound cargo vessels, outbound tankers, etc.) may be compared temporally and spatially to determine performance trends. These trends may be analyzed with respect to a wide variety of environmental and operational forcings such as shoal development, regulatory boundaries, night-and-day cycles, etc. Scully and Mitchell (2013) performed hypothesis testing of draft and tide relationships for a 1-year sample of inbound and outbound vessels of varying drafts at Charleston,

SC. The authors found that outbound vessels drafting greater than 40 ft demonstrated a statistically significant preference for higher water levels, indicating that the timing of their departures is dependent upon high tide. However, inbound vessels drafting over 40 ft did not demonstrate a statistically significant preference for high tide. The exact reasons behind these differences for inbound and outbound vessels will require further investigation; however, this approach provides a straightforward way to focus on the subsets of vessels that are most directly dependent upon tidal elevations and, therefore, the navigable depths within a channel. Although the study looked at one location in one port, it serves as a proof of concept for quantification of vessel performance using AIS data. The results of further study on the topic may be useful to inform O&M, policy, planning, and design decisions.

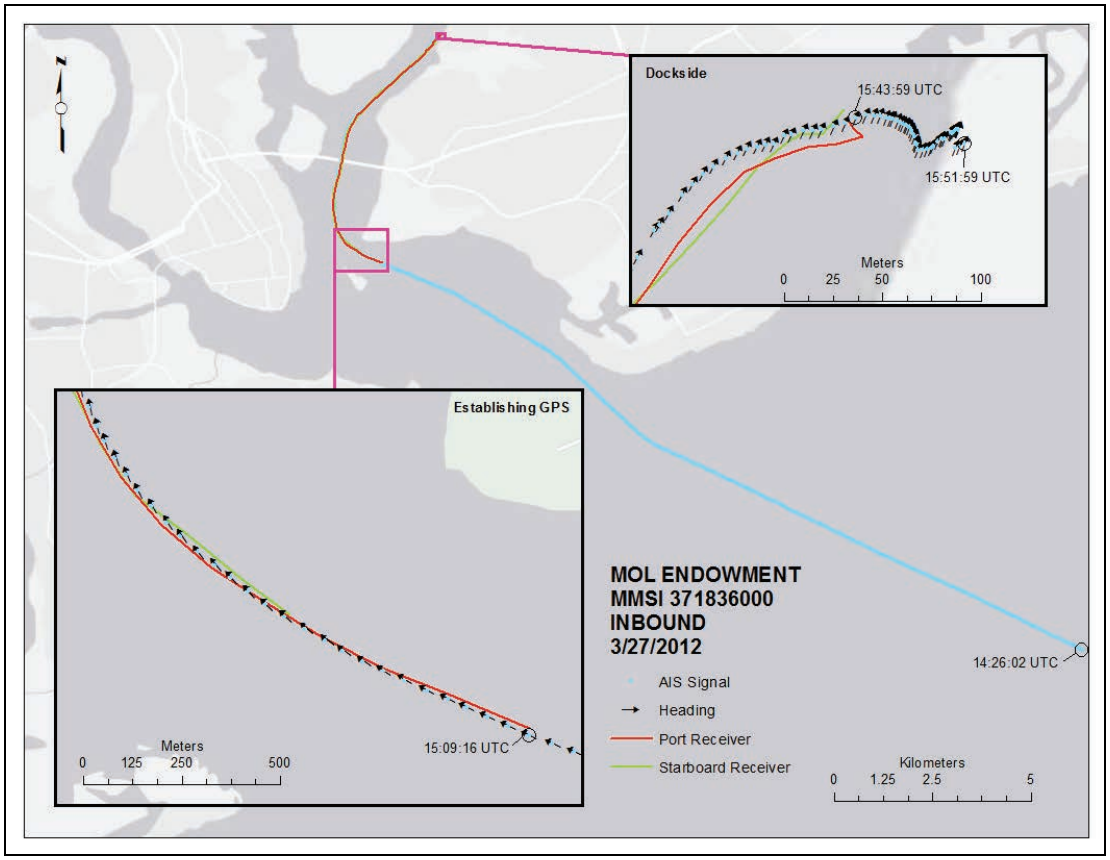

Figure 2. GPS Data collected by field observation team and AIS data extracted from the historical aggregate record.

Incident Investigations. Individual vessel transits can be pulled from the AIS data archive and analyzed to help determine causes and contributing factors in maritime incidents. For example, Burns Harbor, IN, has seen at least two vessel groundings on approach to the main entrance channel in recent years, one in April 2012 and another in July 2013. A review of the relevant AIS records, one of which is shown in Figure 3, indicates that in each instance the vessel was able to pivot back to the north after the initial grounding and eventually pull back and resume the approach on an altered course that cleared the shoal. Use of the AIS record allowed Chicago District personnel to pinpoint the location of the shoal, direct dredging resources, and revise notice to mariners accordingly.

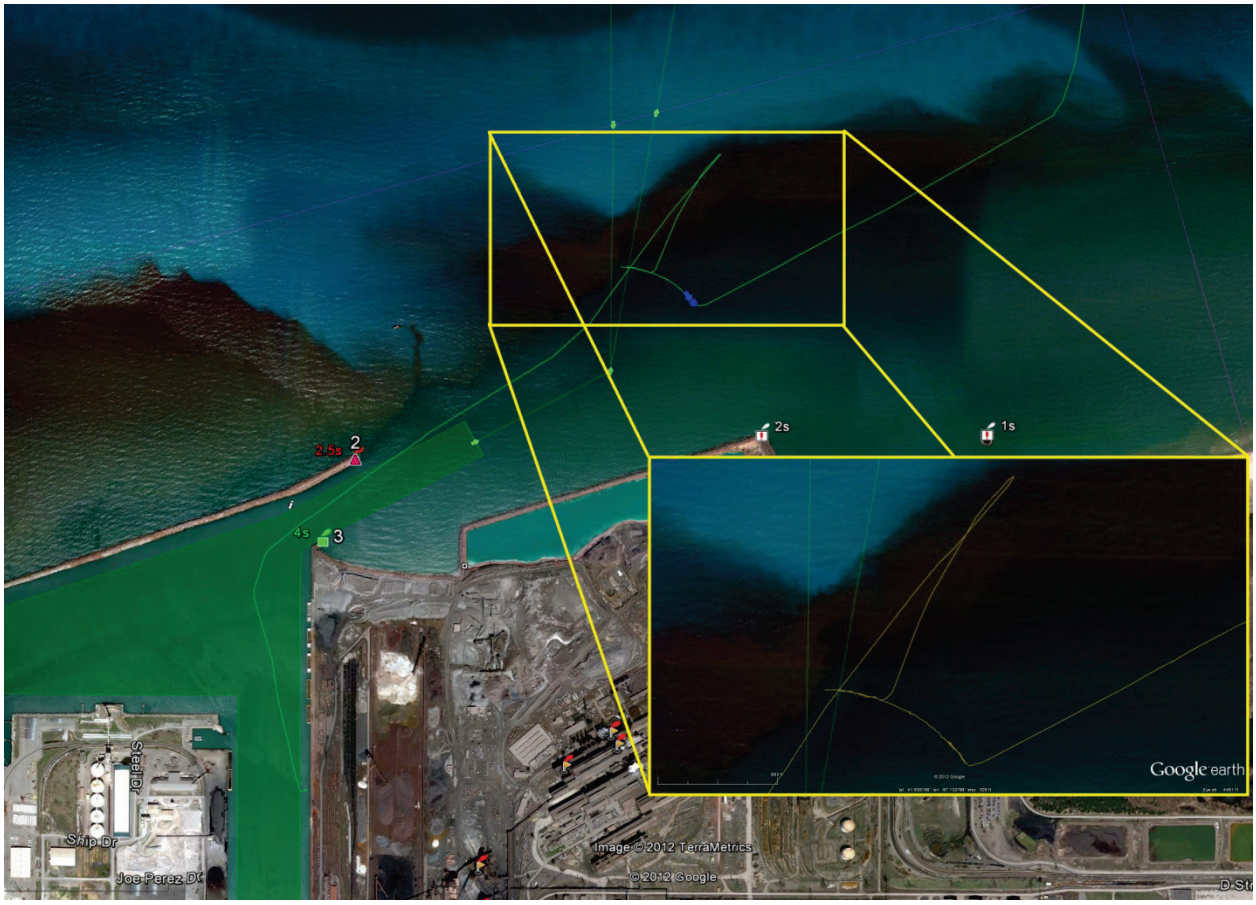

Figure 3. Archived AIS vessel track of vessel grounding at Burns Harbor, IN in April, 2012.

AIS DATA ANALYSIS TOOL: As mentioned, the CIRP and NavSys research programs at the U.S. Army Engineer Research and Development Center (ERDC) are currently developing a process for efficient access to, screening, and analysis of AIS data. In addition to streamlined access to archived AIS data via USCG web services, this effort is developing a software application to conduct statistical analysis of AIS records and is focused on quantifying vessel performance to support operational decision making. This development effort should serve to support future research into understanding vessel performance with regard to a wide range of environmental conditions (e.g., waves, currents, tides, etc.), navigable depths in USACE-maintained channels, and operational decisions by the USACE and USCG (e.g., under-keel clearance requirements, daylight restrictions). Figures 4 through 6 provide screenshots of the analysis interface and presently available analyses with descriptions.

The software application allows for areas of interest (AOI) to be established by the user depending on analysis needs. The AOI acts as a spatial filter that limits analysis to underlying data. Vessels can currently be screened based on Specific MMSI, date range, draft, and vessel type. Filtering data within the AOI provides rapid aggregate statistics, including total number of reports, number of unique vessels, and number of unique transits (Figure 1). In the present state, data in the form of CSV files must be assigned to populate position and static information. However, the ultimate intent of this development effort is to provide access to an enterprise data-storage architecture that will allow AIS data in a variety of file types to be analyzed and displayed.

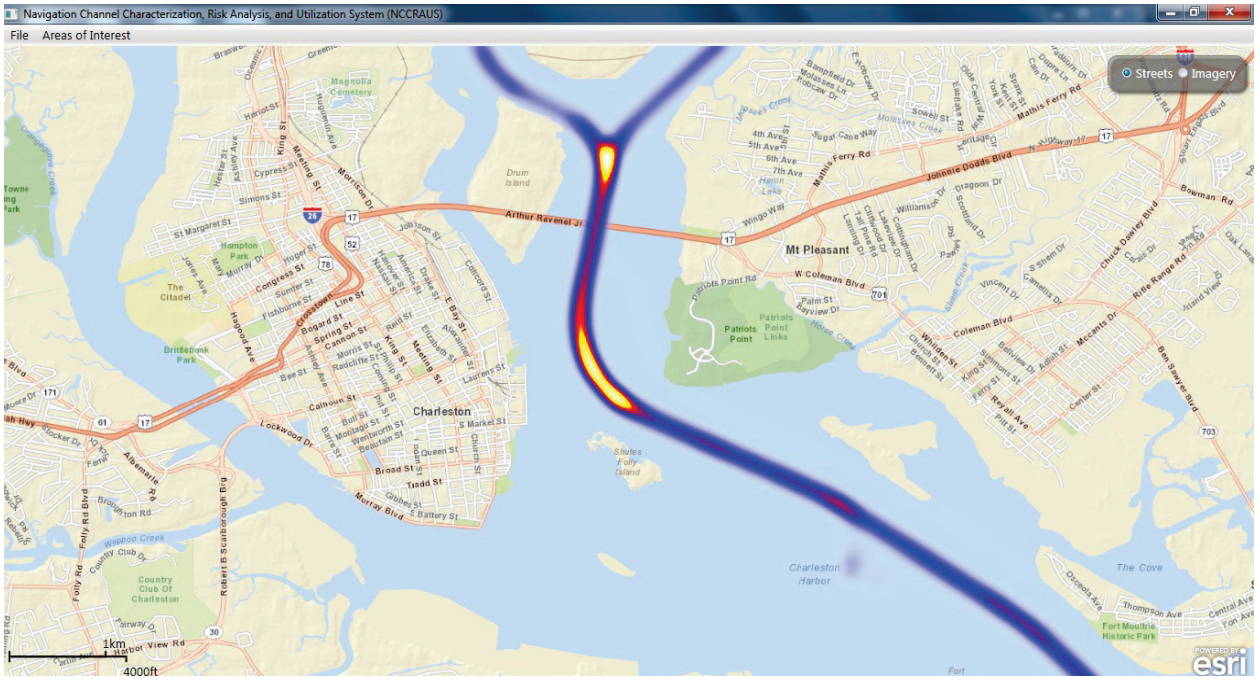

Figure 4. Charleston Harbor Heat Map.

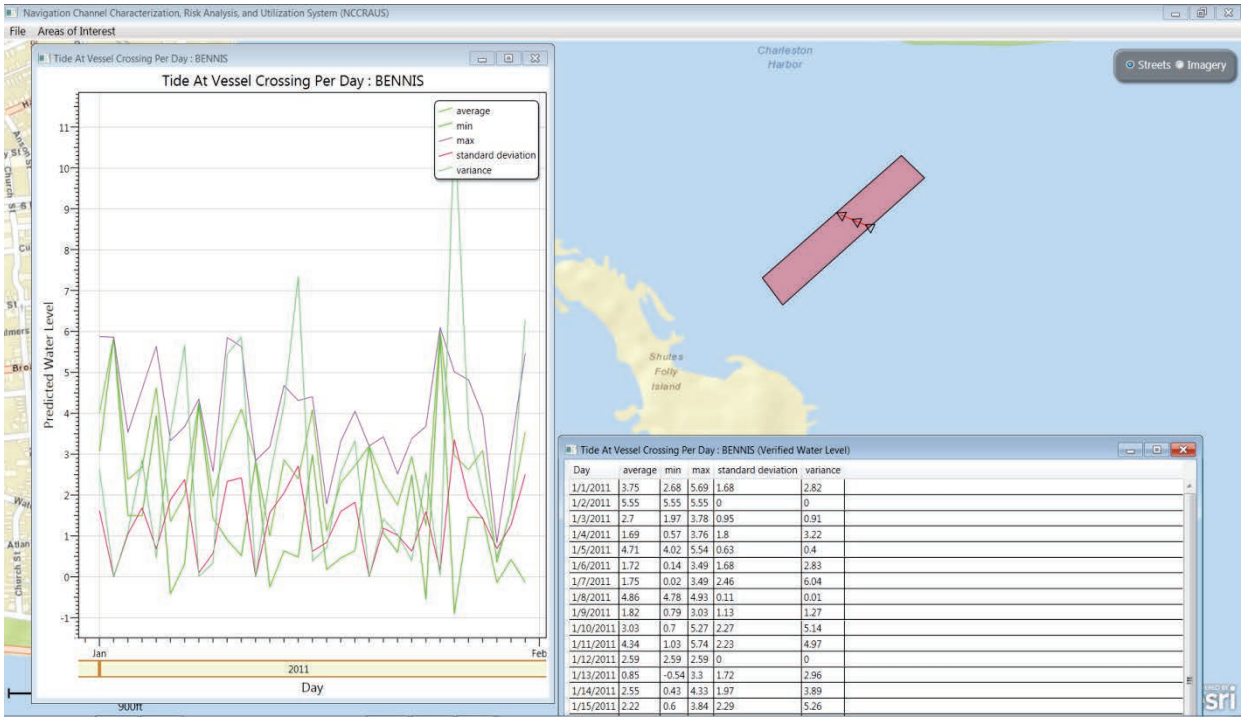

Figure 5. Vessel data correlation with environmental parameters (6-minute, water-level observations).

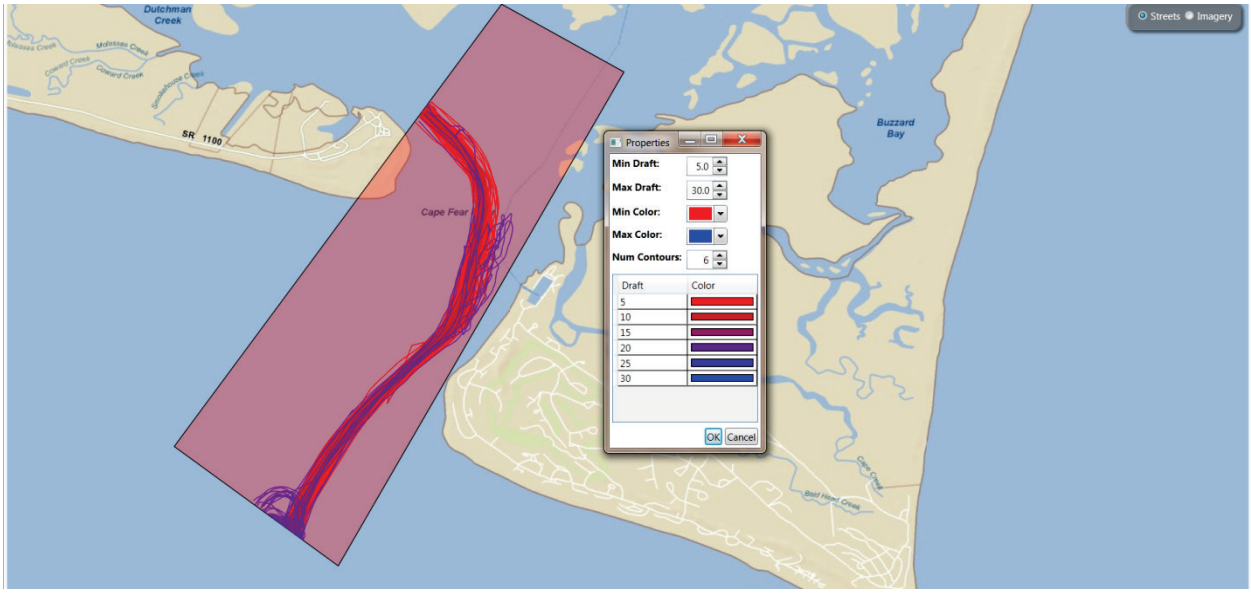

Figure 6. Vector draft analysis. Visualizes the spatial distribution of vessels by draft according to specified increment.

SUMMARY: AIS technology provides USACE practitioners with a data-rich capability for quantifying the complex and dynamic interactions between commercial shipping vessels and dredged channels, coastal structures, inland locks and dams, and other navigation infrastructure. The magnitude of available archival data, the near-complete coverage of US coastal waters, and the relative ease with which it can be obtained and analyzed give AIS data enormous potential as a remote sensing technology for performance evaluation of navigation infrastructure. This CHETN provides background on AIS data and summarizes some of the initial applications and studies underway in support of USACE navigation mission execution. Future development of the AIS data-analysis package discussed here will be driven by the needs of USACE-practitioners working to manage and maintain navigation projects across the country.

POINT OF CONTACT: This CHETN is a joint product of the Coastal Inlets Research Program (CIRP) and the Navigation Systems (NavSys) Research Program at the U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory. Questions about this technical note can be addressed to Dr. Ned Mitchell (Phone: 601-634-2022, e-mail: *Kenneth.n.mitchell@usace.army.mil*). For information about the CIRP, please contact the program manager, Dr. Julie D. Rosati, at 202-761-1850 or *Julie.d.rosati@usace.army.mil*. For information about the NavSys program, please contact the program manager, Mr. Eddie Wiggins, at 601-634-2471 or *Charles.e.wiggins@usace.army.mil*. This technical note should be cited as follows:

> Scully, B., and K. N. Mitchell. 2015. *Archival automatic identification system (AIS) data for navigation project performance evaluation*. ERDC/CHL CHETN-IX-40. Vicksburg, MS: U.S. Army Engineer Research and Development Center. *http://chl.erdc.usace.army.mil/chetn*

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